

⑫ **EUROPEAN PATENT APPLICATION**

⑰ Application number: 84303804.3

⑸ Int. Cl.<sup>2</sup>: **C 08 F 10/00**  
**C 08 F 4/62**

⑱ Date of filing: 05.06.84

⑳ Priority: 06.06.83 US 501740

⑴ Applicant: **Exxon Research and Engineering Company**  
**P.O.Box 390 180 Park Avenue**  
**Florham Park New Jersey 07932(US)**

㉑ Date of publication of application:  
12.12.84 Bulletin 84/50

⑵ Inventor: **Ewen, John Alexander**  
**16615 Kentwood**  
**Houston Texas(US)**

㉒ Designated Contracting States:  
BE DE FR GB IT NL SE

⑶ Inventor: **Welborn, Howard Curtis, Jr.**  
**1502 Driscoll Street**  
**Houston Texas(US)**

⑷ Representative: **Northover, Robert Frank et al,**  
**ESSO Chemical Limited Esso Chemical Research Centre**  
**P.O. Box 1**  
**Abingdon Oxfordshire, OX13 6BB(GB)**

⑸ Process and catalyst for producing poly-ethylene having a broad molecular weight distribution.

⑹ Polyolefins having a broad molecular weight distribution are obtained by polymerizing ethylene or higher alpha-olefins in the presence of a catalyst system comprising two or more metallocenes each having different propagation and termination rate constants and alumoxane.

**EP 0 128 045 A1**

PROCESS AND CATALYST FOR PRODUCING POLYETHYLENE HAVING  
A BROAD MOLECULAR WEIGHT DISTRIBUTION

1       The present invention concerns catalyst and process for the  
2 polymerization of ethylene. More particularly, the invention  
3 relates to catalysts and process for the polymerization of  
4 ethylene to polyethylene having a broad or multimodal molecular  
5 weight distribution.

6       It is known that certain metallocenes such as  
7 bis(cyclopentadienyl) titanium or zirconium dialkyls in  
8 combination with aluminum alkyl co-catalyst, form homogeneous  
9 catalyst systems useful for the polymerization of ethylene.  
10 German Patent Application 2,608,863 discloses the use of a  
11 catalyst system for the polymerization of ethylene consisting  
12 of bis(cyclopentadienyl)titanium dialkyl, aluminum trialkyl and  
13 water. German Patent Application 2,608,933 discloses an  
14 ethylene polymerization catalyst system consisting of zirconium  
15 metallocenes of the general formula  
16  $(\text{cyclopentadienyl})_n\text{ZrY}_{4-n}$ , wherein n stands for a number in  
17 the range of 1 to 4, Y for R,  $\text{CH}_2\text{AlR}_2$ ,  $\text{CH}_2\text{CH}_2\text{AlR}_2$  and  
18  $\text{CH}_2\text{CH}(\text{AlR}_2)_2$  wherein R stands for alkyl or metallo alkyl;  
19 an aluminum trialkyl cocatalyst and water.

20       European Patent Appln. No. 0035242 discloses a process for  
21 preparing ethylene and atactic propylene polymers in the  
22 presence of a halogen-free Ziegler catalyst system of (1) a  
23 cyclopentadienyl compound of the formula  
24  $(\text{cyclopentadienyl})_n\text{MeY}_{4-n}$  in which n is an integer from 1  
25 to 4, Me is a transition metal, especially zirconium, and Y is  
26 either hydrogen, a  $\text{C}_1\text{-C}_5$  alkyl or metallo alkyl group or a  
27 group of the general formula  $\text{CH}_2\text{AlR}_2$ ,  $\text{CH}_2\text{CH}_2\text{AlR}_2$  and  
28  $\text{CH}_2\text{CH}(\text{AlR}_2)_2$  in which R represents a  $\text{C}_1\text{-C}_5$  alkyl or  
29 metallo alkyl group, and (2) an alumoxane.

30       The above disclosures demonstrate the usefulness of certain  
31 specific metallocenes in combination with certain aluminum  
32 compounds for the polymerization of ethylene and particularly  
33 polymerization at a high activity. The above described  
34 catalysts comprising titanium and zirconium metallocenes being  
35 homogeneous, produce polyethylenes of narrow molecular weight  
36 distribution (MWD) i.e.  $\bar{M}_w/\bar{M}_n$  of from 2-4. Hence, the

1 references neither disclose polyethylenes having a broad  
2 molecular weight distribution and/or a multimodal molecular  
3 weight distribution, nor how to obtain such polyethylenes.

4 U. S. Patent 4,310,648 discloses a catalytic reaction  
5 product of a titanium compound, a zirconium compound, an  
6 organomagnesium compound and a halide source. The reaction  
7 product (a heterogeneous catalyst) when employed in combination  
8 with aluminum alkyls is useful for the production at high  
9 activity of broad molecular weight polyethylenes.

10 U. S. Patent 4,361,685 discloses the use of organic soluble  
11 chromium and zirconium compounds to be employed in combination  
12 with a supported catalyst system comprising an organometallic  
13 activating agent and a trivalent or tetravalent titanium  
14 compound. The polymers obtained have a high molecular weight  
15 and a narrow molecular weight distribution.

16 In "Molecular Weight Distribution And Stereoregularity Of  
17 Polypropylenes Obtained With  
18  $Ti(OC_4H_9)_4/Al_2(C_2H_3)_3$  Catalyst System"; Polymer,  
19 Pg. 469-471, 1981, Vol. 22, April, Doi, et al disclose  
20 propylene polymerization with a catalyst which at about 41°C  
21 obtains a soluble catalyst and insoluble catalyst fraction, one  
22 with "homogeneous catalytic centres" and the other with  
23 "heterogeneous catalytic centres". The polymerization at that  
24 temperature obtains polypropylene having a bimodal molecular  
25 weight distribution.

26 It is highly desirable to have for many application, such  
27 as an extrusion and molding processes, polyethylenes which have  
28 a broad molecular weight distribution of the unimodal and/or  
29 the multimodal type. Such polyethylenes evidence excellent  
30 processability, i.e., they can be processed at a faster  
31 throughput rate with lower energy requirements and at the same  
32 time such polymers would evidence reduced melt flow  
33 perturbations.

34 In view of the foregoing problems, it would be highly  
35 desirable to provide a polymerization catalyst system of high  
36 activity to produce high quality ethylene polymers which

1 evidence broad molecular weight distribution. It is  
 2 furthermore highly desirable to be able to produce the ethylene  
 3 polymers directly in a single reactor, i.e., without having to  
 4 blend polyethylenes having different molecular weights and  
 5 distributions in order to obtain the advantages of this  
 6 invention.  
 7

### 8 SUMMARY OF THE INVENTION

9 The present invention provides polyethylene having a broad  
 10 molecular weight and/or a multimodal molecular weight  
 11 distribution. The polyethylenes are obtained directly from a  
 12 single polymerization process, i.e., the polyethylenes of this  
 13 invention are obtained without requiring blending techniques.  
 14 The invention furthermore provides a catalyst system for the  
 15 polymerization of ethylene directly to polyethylene having a  
 16 broad molecular weight distribution especially a multimodal  
 17 molecular weight distribution, and particularly a bimodal MWD.  
 18 The invention further provides a process for polymerizing  
 19 ethylene in the presence of the catalyst system.  
 20

21 Accordingly, there is provided catalyst systems and  
 22 especially systems for the polymerization of ethylene to  
 23 polyethylene having a broad molecular weight distribution and  
 24 especially a bimodal or multimodal molecular weight  
 25 distribution; said catalyst system comprising (a) at least two  
 26 different metallocenes each having different propagation and  
 27 termination rate constants for ethylene polymerizations and (b)  
 28 an alumoxane. The metallocenes employed in accordance with  
 29 this invention are organometallic coordination compounds which  
 30 are cyclopentadienyl derivatives of a transition metal of Group  
 31 4b, 5b and 6b metals of the Periodic Table and include mono, di  
 32 and tricyclopentadienyls and their derivatives of the  
 33 transition metals. The metallocenes can be represented by the  
 34 general formula  $(C_5R'_m)_pR''_s(C_5R'_m)_2MeQ_{3-p}$  or  
 35  $R''_s(C_5R'_m)MeQ'$ , wherein  $(C_5R'_m)$  is a cyclopentadienyl  
 or substituted cyclopentadienyl, each  $R'$ , which can be the same

1 or different, is hydrogen or a hydrocarbyl radical such as  
2 alkyl, alkenyl, aryl, alkylaryl, or arylalkyl radical having  
3 from 1 to 20 carbon atoms or two carbon atoms of the  
4 cyclopentadienyl ring are joined together to form a  $C_4-C_6$   
5 ring,  $R''$  is a  $C_1-C_4$  alkylene radical, a dialkyl germanium  
6 or silicone or an alkyl phosphine or amine radical bridging two  
7 ( $C_5R'_m$ ) rings,  $Q$  is a hydrocarbon radical such as aryl,  
8 alkyl, alkenyl, alkylaryl, or arylalkyl radical having from 1  
9 to 20 carbon atoms or halogen and can be the same or different,  
10  $Q'$  is an alkylidene radical having from 1 to 20 carbon  
11 atoms,  $Me$  is a Group 4b, 5b and 6b metal of the Periodic Table  
12 (Chemical Rubber Company's Handbook of Chemistry and Physics,  
13 48th Edition),  $s$  is 0 or 1,  $p$  is 0, 1 or 2; when  $p = 0$ ,  $s = 0$ ;  
14  $m$  is 4 when  $s$  is 1 and  $m$  is 5 when  $s$  is 0.

15 The present invention also provides a process for producing  
16 polyethylenes having a high molecular weight as well as a broad  
17 molecular weight distribution and especially MWD of the bimodal  
18 type. The process comprises polymerizing ethylene  
19 alone or ethylene with minor amounts of higher alpha-olefins in  
20 the presence of the homogeneous catalyst system described above.

21 The present invention furthermore provides high molecular  
22 weight polyethylene having a bimodal molecular weight  
23 distribution.

24 It is highly surprising that two different metallocenes in  
25 combination with an alumoxane can produce polyethylene having a  
26 broad MWD since the individual metallocenes with an alumoxane  
27 generally obtains polyethylene having a narrow MWD. In  
28 accordance with this invention, however, one can advantageously  
29 tailor polyethylene having desired molecular weights and  
30 molecular weight distributions by the judicious selection of  
31 metallocenes.

#### 32 BRIEF DESCRIPTION OF THE FIGURES

33 Figure 1 is a plot of the molecular weight distribution of  
34 polyethylene prepared as in Example 1 and in accordance with  
35 this invention.

1 Figure 2 is a plot of the molecular weight distribution of  
2 polyethylene prepared as in comparative example 1B showing a  
3 narrow unimodal MWD.

4 Figure 3 is a plot of the molecular weight distribution of  
5 polyethylene prepared as in comparative example 1A showing a  
6 narrow unimodal MWD.

7 Figure 4 is a plot of the molecular weight distribution of  
8 polyethylene prepared as in example 2 and showing a bimodal MWD.

9 Figure 5 is a plot of the molecular weight distribution of  
10 polyethylene prepared as in example 3 showing a bimodal MWD.

11 DETAILED DESCRIPTION OF THE INVENTION

12 The present invention is directed towards a catalytic  
13 process for the polymerization of ethylene to high molecular  
14 weight polyethylenes evidencing a broad and/or multimodal  
15 molecular weight distribution. The polymers are intended for  
16 fabrication into articles by extrusion, injection molding,  
17 thermoforming, rotational molding, and the like. In  
18 particular, the polymers of this invention are homopolymers of  
19 ethylene, however, minor amounts of higher alpha-olefins having  
20 from 3 to 10 carbon atoms and preferably 4 to 8 carbon  
21 atoms can be copolymerized with ethylene. Illustrative of the  
22 higher alpha-olefins are butene-1, hexene-1 and octene-1.

23 In the process of the present invention, ethylene, either  
24 alone or together with minor amounts of alpha-olefins, is  
25 polymerized in the presence of a catalyst system comprising at  
26 least two metallocenes and an alumoxane.

27 The alumoxanes are well known in the art and are polymeric  
28 aluminum compounds which can be represented by the general  
29 formulae  $(R-Al-O)_n$  which is a cyclic compound and  
30  $R(R-Al-O)_nAlR_2$ , which is a linear compound. In the  
31 general formula R is a  $C_1-C_5$  alkyl group such as, for  
32 example, methyl, ethyl, propyl, butyl and pentyl and n is an  
33 integer from 1 to 20. Most preferably, R is methyl.  
34 Generally, in the preparation of alumoxanes from, for example,

1 aluminum trimethyl and water, a mixture of the linear and  
2 cyclic compounds are obtained.

3 The alumoxanes can be prepared in various ways.  
4 Preferably, they are prepared by contacting water with a  
5 solution of aluminum trialkyl, such as, for example, aluminum  
6 trimethyl, in a suitable organic solvent such as benzene or an  
7 aliphatic hydrocarbon. For example, the aluminum alkyl is  
8 treated with water in the form of a moist solvent or the  
9 aluminum alkyl such as aluminum trimethyl can be desirably  
10 contacted with a hydrated salt such as hydrated copper sulfate.

11 Preferably, the alumoxane is prepared in the presence of a  
12 hydrated copper sulfate. The method comprises treating a  
13 dilute solution of aluminum trimethyl in, for example, toluene,  
14 with copper sulfate represented by the general formula  
15  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ . The ratio of copper sulfate to aluminum  
16 trimethyl is desirably about 1 mole of copper sulfate for 5  
17 moles of aluminum trimethyl. The reaction is evidenced by the  
18 evolution of methane.

19 The metallocenes employed each should have different  
20 propagation and termination rate constants with respect to  
21 ethylene polymerization. Such rate constants can be determined  
22 by one of ordinary skill in the art. The metallocenes are the  
23 organometallic coordination compound which are the mono, di and  
24 tricyclopentadienyls and their derivatives of a transition  
25 metal of Group 4b, 5b and 6b metals of the Periodic Table. The  
26 more desirable metallocenes employed in accordance with the  
27 invention are represented by the general formula  
28  $(\text{C}_5\text{R}'_m)_p \text{R}''_s (\text{C}_5\text{R}'_m) \text{MeQ}_{3-p}$  and  
29  $\text{R}''_s (\text{C}_5\text{R}'_m)_2 \text{MeQ}'$  wherein  $(\text{C}_5\text{R}'_m)$  is cyclopentadienyl  
30 or substituted cyclopentadienyl, each R' is the same or  
31 different and is hydrogen or a hydrocarbyl radical such as  
32 alkyl, alkenyl, aryl, alkylaryl, or arylalkyl radicals  
33 containing from 1 to 20 carbon atoms or two adjacent carbon  
34 atoms are joined together to form a  $\text{C}_4$ - $\text{C}_6$  ring, R'' is a  
35  $\text{C}_1$ - $\text{C}_4$  alkylene radical, a dialkyl germanium or silicone or  
36 an alkyl phosphine or amine radical bridging two  $(\text{C}_5\text{R}'_m)$

1 rings, Q is a hydrocarbyl radical such as aryl, alkyl, alkenyl,  
 2 alkylaryl, or arylalkyl radical having from 1-20 carbon atoms  
 3 or halogen and can be the same or different, Q' is an  
 4 alkylidene radical having from 1 to 20 carbon atoms, s is  
 5 0 or 1, p is 0, 1 or 2; when p is 0, s is 0; m is 4 when s is 1  
 6 and m is 5 when s is 0 and Me is a Group 4b, 5b or 6b metal of  
 7 the Periodic Table.

8 Exemplary hydrocarbyl radicals are methyl, ethyl, propyl,  
 9 butyl, amyl, isoamyl, hexyl, isobutyl, heptyl, octyl, nonyl,  
 10 decyl, cetyl, 2-ethylhexyl, phenyl, and the like.

11 Exemplary alkylene radicals are methylene, ethylene,  
 12 propylene, and the like.

13 Exemplary halogen atoms include chlorine, bromine and  
 14 iodine and of these halogen atoms, chlorine is preferred.

15 Exemplary of the alkylid radicals is methylidene,  
 16 ethylidene and propylidene.

17 The multiple metallocene system usefully employed in  
 18 accordance with this invention are preferably the mono, bi and  
 19 tricyclopentadienyl or substituted cyclopentadienyl titanium  
 20 (IV) and zirconium (IV) compounds represented by the general  
 21 formula.

22 Illustrative but non-limiting examples of the titanocenes  
 23 which can be usefully employed in accordance with this  
 24 invention are monocyclopentadienyl titanocenes, such as  
 25 cyclopentadienyl titanium trichloride,

26 pentamethylcyclopentadienyl titanium trichloride;  
 27 bis(cyclopentadienyl) titanium diphenyl, the carbene  
 28 represented by the formula  $Cp_2Ti=CH_2 \cdot Al(CH_3)_2Cl$ ,  
 29 and derivatives of this reagent such as

30  $Cp_2Ti=CH_2 \cdot Al(CH_3)_3$ ,  $(Cp_2TiCH_2)_2$ ,

31  $Cp_2TiCH_2CH(CH_3)CH_2$ ,  $Cp_2Ti=CHCH_2CH_2$ ,

32  $Cp_2Ti=CH_2 \cdot AlR''''_2Cl$ , wherein Cp is a cyclopentadienyl  
 33 or substituted cyclopentadienyl radical, and R'''' is an alkyl,  
 34 aryl or alkylaryl radical having from 1-18 carbon atoms;  
 35 substituted bis(Cp)Ti(IV) compounds such as bis(indenyl)Ti



1 diphenyl or dichloride, bis(methylcyclopentadienyl)Ti diphenyl  
 2 or dihalides and other dihalide complexes; dialkyl, trialkyl,  
 3 tetra-alkyl and penta-alkyl cyclopentadienyl titanium  
 4 compounds, such as bis(1,2-dimethylcyclopentadienyl)Ti diphenyl  
 5 or dichloride, bis(1,2-diethylcyclopentadienyl)Ti diphenyl or  
 6 dichloride and other dihalide complexes.

7 Illustrative but non-limiting examples of the zirconocenes  
 8 which can be usefully employed in accordance with this  
 9 invention are monocyclopentadienyl zirconocenes, such as  
 10 cyclopentadienyl zirconium trichloride, pentamethyl  
 11 cyclopentadienyl zirconium trichloride;  
 12 bis(cyclopentadienyl)zirconium diphenyl,  
 13 bis(cyclopentadienyl)zirconium dimethyl, the alkyl substituted  
 14 cyclopentadienes, such as bis(ethyl cyclopentadienyl)zirconium  
 15 dimethyl, bis( $\beta$ -phenylpropylcyclopentadienyl)zirconium  
 16 dimethyl, bis(methylcyclopentadienyl)zirconium dimethyl, and  
 17 dihalide complexes of the above. Di-alkyl, tri-alkyl,  
 18 tetra-alkyl, and penta-alkyl cyclopentadienes, such as  
 19 bis(pentamethylcyclopentadienyl)zirconium dimethyl, bis  
 20 (1,2-dimethylcyclopentadienyl)zirconium dimethyl,  
 21 bis(1,3-diethylcyclopentadienyl)zirconium dimethyl and dihalide  
 22 complexes of the above. Silicone, phosphorus, and carbon  
 23 bridged cyclopentadiene complexes such as  
 24 dimethylsilyldicyclopentadienyl zirconium dimethyl or dihalide,  
 25 methylphosphine dicyclopentadienyl zirconium dimethyl or  
 26 dihalide, and methylene dicyclopentadienyl zirconium dimethyl  
 27 or dihalide, carbenes represented by the formulae  
 28  $Cp_2Zr=CH_2P(C_6H_5)_2CH_3$ , and derivatives of these  
 29 compounds such as  $Cp_2ZrCH_2CH(CH_3)CH_2$ .

30 Bis(cyclopentadienyl)hafnium dichloride,  
 31 bis(cyclopentadienyl)hafnium dimethyl,  
 32 bis(cyclopentadienyl)vanadium dichloride are illustrative of  
 33 other metallocenes.

34 The ratio of aluminum in the alumoxane to total metal in  
 35 the metallocenes can be in the range of 0.5:1 to  
 36  $10^5:1$ , and preferably 5:1 to  $10^3:1$ . The molar  
 37 ratio of zirconocene to titanocene can vary over a wide range

1 and in accordance with this invention the only limitation on  
2 the molar ratios is the breadth of the MW distribution or the  
3 degree of bimodality desired in the product polymer.

4 Desirably, the zirconocene to titanocene molar ratio will be  
5 1:100 to 100:1, and preferably 1:10 to 1:1.

6 The solvents used in the preparation of the catalyst system  
7 are inert hydrocarbons, in particular a hydrocarbon that is  
8 inert with respect to the catalyst system. Such solvents are  
9 well known and include, for example, butane, isobutane,  
10 pentane, hexane, heptane, octane, cyclohexane,  
11 methylcyclohexane, toluene, xylene and the like.

12 The catalyst systems described herein are suitable for the  
13 polymerization of ethylene either in solution, slurry or gas  
14 phase over a wide range of temperatures and pressures. For  
15 example, such temperatures may be in the range of  $-60^{\circ}\text{C}$   
16 to  $280^{\circ}\text{C}$  and especially in the range of  $50^{\circ}\text{C}$  to  
17  $160^{\circ}\text{C}$ . The pressures employed in the process of the present  
18 invention are those well known for, for example, in the range  
19 of 1 to 500 atmospheres and even greater.

20 In a solution phase polymerization the alumoxane and  
21 metallocene can be employed as a homogeneous catalyst system.  
22 The alumoxane is preferably dissolved in a suitable solvent,  
23 typically in inert hydrocarbon solvent such as toluene, xylene,  
24 and the like in molar concentrations of 0.1M to 3M,  
25 however, greater or lesser amounts can be employed.

26 The soluble metallocenes can be converted to supported  
27 heterogeneous catalyst by depositing said metallocenes on  
28 typical catalyst supports such as, for example, silica,  
29 alumina, and polyethylene. The solid catalysts in combination  
30 with an alumoxane can be usefully employed in slurry and gas  
31 phase olefin polymerization.

32 After polymerization and deactivation of the catalyst, the  
33 product polymer can be recovered by processes well known in the  
34 art for removal of deactivated catalysts and solution. The  
35 solvents may be flashed off from the polymer solution and the  
36 obtained polymer extruded into water and cut into pellets or  
37 other suitable comminuted shapes. Pigments, antioxidants and

1 other additives, as is known in the art, may be added to the  
2 polymer.

3 The polymer product obtained in accordance with this  
4 invention will have an average molecular weight in the range of  
5 500 to 2,000,000 and preferably 10,000 to  
6 500,000. The polymer will also have concentrations of average  
7 molecular weights in the range of 500 to 100,000  
8 and 100,000 to 1,000,000 for each sample.

9 The polymers produced by the process of this present  
10 invention are capable of being fabricated into a wide variety  
11 of articles, as is known for homopolymers of ethylene and  
12 copolymers of ethylene and higher alpha-olefins. The present  
13 invention is illustrated by the following examples.

14 In the examples following the molecular weights were  
15 determined on a Water's Associates Model No. 150C GPC (Gel  
16 Permeation Chromatography). The measurements were made by  
17 dissolving polymer samples in hot trichlorobenzene (TCB) and  
18 filtered. The GPC runs were performed at 145°C in TCB at 1.5  
19 ml/min using two Shodex A80 M/S Gel columns of 9.4 mm internal  
20 diameter from Perkin Elmer Inc. 300 milliliter of 3.1 percent  
21 solutions in TCB were injected and the chromatographic runs  
22 monitored at sensitivity equal -64 and scale factor equal 65.  
23 The samples were run in duplicate. The integration parameters  
24 were obtained with a Water's Associates data module. An  
25 antioxidant, N-phenyl-2-naphthylamine, was added to all samples.

#### 26 EXAMPLES

27 In the examples following the alumoxane was prepared in the  
28 following manner:

29 600cc of a 14.5% solution of trimethylaluminum (TMA) in  
30 heptane was added in 30cc increments at 5 minute intervals,  
31 with rapid stirring, to 200cc toluene in a Zippoclave reactor  
32 under nitrogen and maintained at 100°C. Each increment was  
33 immediately followed by the addition of 0.3cc water. The  
34 reactor was vented of methane after each addition. Upon

1 completion of the addition, the reactor was stirred for 6 hours  
2 while maintaining the temperature at 100°C. The mixture,  
3 contains soluble alumoxane and insoluble materials, is allowed  
4 to cool to room temperature and settle. The clear solution  
5 containing the soluble alumoxane is separated by decantation  
6 from the solids.

#### 7 Example 1

8 A 1-liter stainless steel pressure vessel, equipped with an  
9 incline blade stirrer, an external water jacket for temperature  
10 control, a septum inlet and vent line, and a regulated supply  
11 of dry ethylene and nitrogen, was dried and deoxygenated with a  
12 nitrogen flow. 500cc of dry, degassed toluene was introduced  
13 directly into the pressure vessel. 20.0cc of alumoxane  
14 solution (0.64 molar in total aluminum) was injected into the  
15 vessel by a gas tight syringe through the septum inlet and the  
16 mixture was stirred at 1,200 rpms and 50°C for 5 minutes at 0  
17 psig of nitrogen. 0.091 mg bis(pentamethyl  
18 cyclopentadienyl)zirconium dimethyl dissolved in 1.0 ml of dry,  
19 distilled toluene was injected through the septum inlet into  
20 the vessel followed by the injection of 0.906 mg  
21 bis(cyclopentadienyl) titanium diphenyl in 10 ml of toluene.  
22 After 1 minute, ethylene at 50 psig was admitted and while the  
23 reaction vessel was maintained at 50°C. The ethylene was  
24 passed into the vessel for 40 minutes at which time the  
25 reaction was stopped by rapidly venting and cooling the  
26 reactor. 20.1 gms of powdery white polyethylene having a  $\bar{M}_n$  of  
27 58,600 and a  $\bar{M}_w$  of 323,000 with a molecular weight distribution  
28 of 5.51. The GPC as shown in Fig. 1 showed a bimodal molecular  
29 weight distribution.

#### 30 Comparative Example 1A

31 Ethylene was polymerized under conditions identical to that  
32 of Example 1 with the exception that the zirconocene only was  
33 employed in combination with the alumoxane. 0.102 mg of the  
34 zirconocene was employed. 20.6 gm of polyethylene was

1 obtained. The polyethylene had a  $\bar{M}_n$  of 42,000 and  $\bar{M}_w$  of  
2 139,000 with a MWD of 3.31. The GPC as appears in Figure 3  
3 evidenced a unimodal molecular weight distribution.

#### 4 Comparative Example 1B

5 Ethylene was polymerized under conditions identical to that  
6 of Example 1 with the exception that the titanocene only was  
7 employed in combination with the alumoxane. 1.02 mg of the  
8 titanocene was employed. 13.2gm of polyethylene was obtained.  
9 The polyethylene had a  $\bar{M}_n$  of 184,000 and  $\bar{M}_w$  of 558,000 with a  
10 MWD of 3.03. The GPC as appears in Figure 2 evidenced a  
11 unimodal molecular weight distribution.

#### 12 Example 2

13 A 1-liter stainless steel pressure vessel, equipped with an  
14 incline blade stirrer, an external water jacket for temperature  
15 control, a septum inlet and vent line, and a regulated supply  
16 of dry ethylene and nitrogen, was dried and deoxygenated with a  
17 nitrogen flow. 400cc of dry, degassed toluene was introduced  
18 directly into the pressure vessel. 20.0cc of alumoxane (8  
19 mmoles in total aluminum) was injected into the vessel by a gas  
20 tight syringe through the septum inlet and the mixture was  
21 stirred at 1,200 rpms and 80°C for 5 minutes at 0 psig of  
22 nitrogen. 0.015 mg bis(cyclopentadienyl) zirconium dimethyl  
23 dissolved in 1.0 ml of dry, distilled toluene was injected  
24 through the septum inlet into the vessel followed by the  
25 injection of 5.18 mg bis(cyclopentadienyl)titanium diphenyl in  
26 10 ml of toluene. After 1 minute, ethylene at 60 psig was  
27 admitted for 40 minutes while maintaining the reaction vessel  
28 at 80°C. The reaction was stopped by rapidly venting and  
29 cooling. 10.7 gms of powdery white polyethylene having a  $\bar{M}_n$  of  
30 63,000 and a  $\bar{M}_w$  of 490,000 with a molecular weight distribution  
31 of 7.8. The GPC as shown in Fig. 4 showed a bimodal molecular  
32 weight distribution.

**Example 3**

1 A 1-liter stainless steel pressure vessel, equipped with an  
2 incline blade stirrer, an external water jacket for temperature  
3 control, a septum inlet and vent line, and a regulated supply  
4 of dry ethylene and nitrogen, was dried and deoxygenated with a  
5 nitrogen flow. 400cc of dry, degassed toluene was introduced  
6 directly into the pressure vessel. 20.0cc of alumoxane (8  
7 mmoles in total aluminum) was injected into the vessel by a gas  
8 tight syringe through the septum inlet and the mixture was  
9 stirred at 1,200 rpms and 50°C for 5 minutes at 0 psig of  
10 nitrogen. 0.151 mg bis(cyclopentadienyl) zirconium dimethyl  
11 dissolved in 1.0 ml of dry, distilled toluene was injected  
12 through the septum inlet into the vessel followed by the  
13 injection of 5.5 mg bis(cyclopentadienyl) titanium diphenyl in  
14 10 ml of toluene. After 1 minute, ethylene at 60 psig was  
15 admitted for 40 minutes while maintaining the reaction vessel  
16 at 50°C. The reaction was stopped by rapidly venting and  
17 cooling. 13.8 gms of powdery white polyethylene having a  $M_n$  of  
18 16,500 and a  $M_w$  of 89,000 with a molecular weight distribution  
19 of 5.4. The GPC as shown in Fig. 5 showed a bimodal molecular  
20 weight distribution.  
21

**Example 4**

22 A 1-liter stainless steel pressure vessel, equipped with an  
23 incline blade stirrer, an external water jacket for temperature  
24 control, a septum inlet and vent line, and a regulated supply  
25 of dry ethylene and nitrogen, was dried and deoxygenated with a  
26 nitrogen flow. 400cc of dry, degassed toluene was introduced  
27 directly into the pressure vessel. 20.0cc of alumoxane (15  
28 mmoles in total aluminum) was injected into the vessel by a gas  
29 tight syringe through the septum inlet and the mixture was  
30 stirred at 1,200 rpms and 80°C for 5 minutes at 0 psig of  
31 nitrogen. 0.231 mg bis(cyclopentadienyl) zirconium dimethyl  
32 and 0.260 bis(ethylcyclopentadienyl)zirconium dimethyl, each  
33 dissolved in 1.0 ml of dry distilled toluene, were injected  
34 through the septum inlet into the vessel followed by the  
35

1 injection of 0.535 mg bis(cyclopentadienyl)titanium diphenyl in  
2 10 ml of toluene. After 1 minute, ethylene at 60 psig was  
3 admitted for 40 minutes while maintaining the reaction vessel  
4 at 80°C. The reaction was stopped by rapidly venting and  
5 cooling. 24.0 gms of powdery white polyethylene having a  $\bar{M}_n$  of  
6 43,000 and a  $\bar{M}_w$  of 191,000 with a molecular weight distribution  
7 of 4.4.

#### 8 Example 5

9 A 1-liter stainless steel pressure vessel, equipped with an  
10 incline blade stirrer, an external water jacket for temperature  
11 control, a septum inlet and vent line, and a regulated supply  
12 of dry ethylene and nitrogen, was dried and deoxygenated with a  
13 nitrogen flow. 400cc of dry, degassed toluene was introduced  
14 directly into the pressure vessel. 20.0cc of alumoxane (15  
15 mmoles in total aluminum) was injected into the vessel by a gas  
16 tight syringe through the septum inlet and the mixture was  
17 stirred at 1,200 rpms and 80°C for 5 minutes at 0 psig of  
18 nitrogen. .201 mg bis(cyclopentadienyl)zirconium dimethyl and  
19 0.216 mg bis(ethyl cyclopentadienyl)zirconium dimethyl each  
20 dissolved in 1.0 ml of dry distilled toluene were injected  
21 through the septum inlet into the vessel followed by the  
22 injection of 0.506 mg bis(cyclopentadienyl) titanium diphenyl  
23 in 10 ml of toluene. After 1 minute, ethylene at 50 psig was  
24 admitted for 40 minutes while maintaining the reaction vessel  
25 at 80°C. The reaction was stopped by rapidly venting and  
26 cooling. 25.2 gms of powdery white polyethylene having a  $\bar{M}_n$  of  
27 39,700 and a  $\bar{M}_w$  of 168,000 with a molecular weight distribution  
28 of 4.2 and bimodal  $\bar{M}_w$  distribution.

#### 29 Example 6

30 A 1-liter stainless steel pressure vessel, equipped with an  
31 incline blade stirrer, an external water jacket for temperature  
32 control, a septum inlet and vent line, and a regulated supply  
33 of dry ethylene and nitrogen, was dried and deoxygenated with a  
34 nitrogen flow. 500cc of dry, degassed toluene was introduced

1 directly into the pressure vessel. 10.0cc of alumoxane (8  
2 moles total aluminum) was injected into the vessel by a gas  
3 tight syringe through the septum inlet and the mixture was  
4 stirred at 1,200 rpms and 80°C for 5 minutes at 0 psig of  
5 nitrogen. 0.260 mg bis(cyclopentadienyl)zirconium dimethyl and  
6 0.204 mg bis(ethyl cyclopentadienyl)zirconium dimethyl each  
7 dissolved in 1.0 ml of dry distilled toluene were injected  
8 through the septum inlet into the vessel. After 1 minute,  
9 ethylene at 60 psig was admitted for 12 minutes while  
10 maintaining the reaction vessel at 80°C. The reaction was  
11 stopped by rapidly venting and cooling. 32.0 gms of powdery  
12 white polyethylene having a  $\bar{M}_n$  of 47,100 and a  $\bar{M}_w$  of 183,000  
13 with a molecular weight distribution of 3.9.

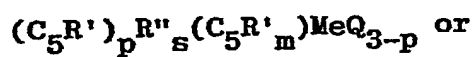


## CLAIMS:

1. A catalyst system for the (co)polymerization of ethylene to polyethylene having a broad molecular weight distribution, said catalyst comprising (a) at least two different metallocenes which are mono, di or tricyclopentadienyl derivatives of a Group 4b, 5b and 6b transition metal each having different propagation and termination rate constants for ethylene polymerizations and (b) an alumoxane.

2. A catalyst system for the (co)polymerization of ethylene to polyethylene having a broad and/or multimodal molecular weight distribution; said catalyst comprising:

(a) at least two or more metallocenes represented by the general formula



$R''_s (C_5R'_m)_2 MeQ'$ , each having a different propagation and termination rate constant, and

(b) an alumoxane

wherein  $(C_5R'_m)$  is a cyclopentadienyl or substituted cyclopentadienyl, each  $R'$  which can be the same or different is hydrogen or a hydrocarbyl radical or two  $R'$  substituents together form a fused  $C_4-C_6$  ring,  $R''$  is a  $C_1-C_4$  alkylene radical, a dialkyl germanium or silicone or alkyl phosphine or amine radical bridging two  $(C_5R'_m)$  rings, each  $Q$ , which may be the same or different, is a hydrocarbon radical or halogen,  $Q'$  is an alkylidene radical having from 1 to 20 carbon atoms,  $Me$  is a Group 4b, 5b or 6b metal,  $s$  is 0 or 1,  $p$  is 0, 1 or 2; when  $p$  is 0,  $s$  is 0;  $m$  is 4 when  $s$  is 1; and  $m$  is 5 when  $s$  is 0.

3. The catalyst system of claim 2 comprising two zirconocenes.

4. The catalyst system of claim 2 comprising two titanocenes.
5. The catalyst system of claim 3 comprising at least 2 zirconocenes and 1 titanocene.
6. The homogeneous catalyst system of claim 4 comprising at least 2 titanocenes and 1 zirconocene.
7. A process for producing polyethylene having a broad and/or multimodal molecular weight distribution comprising polymerizing ethylene in the presence of the catalyst system as claimed in any of claims 1 to 6.
8. Polyethylene having a broad and/or multimodal MWD obtained by polymerizing ethylene in the presence of a catalyst system as claimed in any of claims 1 to 6.
9. The polyethylene of claim 8 having a bimodal MWD.
10. The polyethylene of claim 9 wherein the Mw/Mn ratio is in the range of 2 to 50.

1 / 2

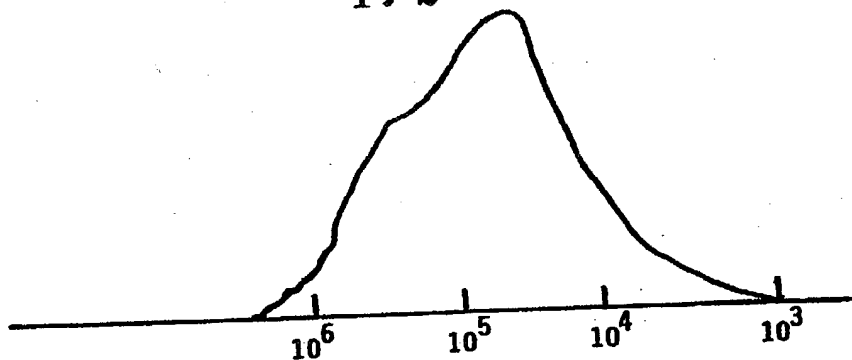


FIG. 1

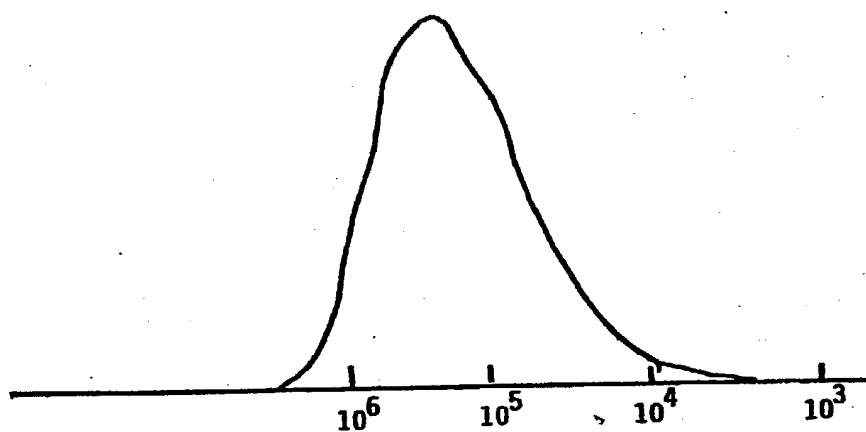


FIG. 2

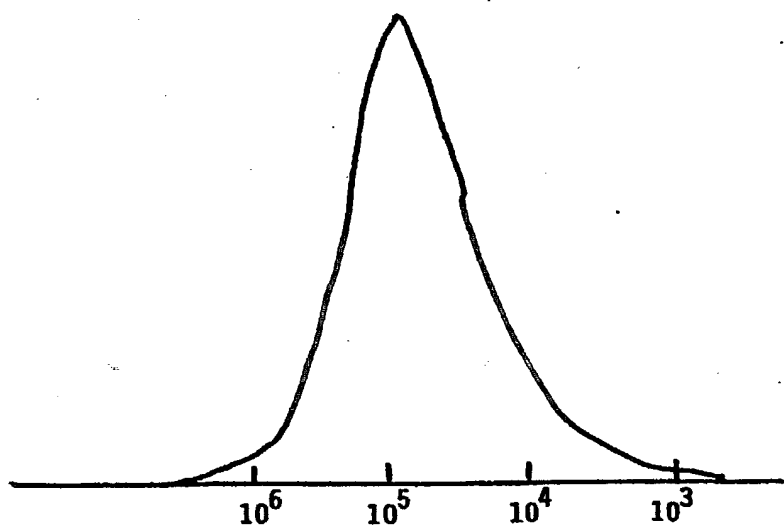


FIG. 3

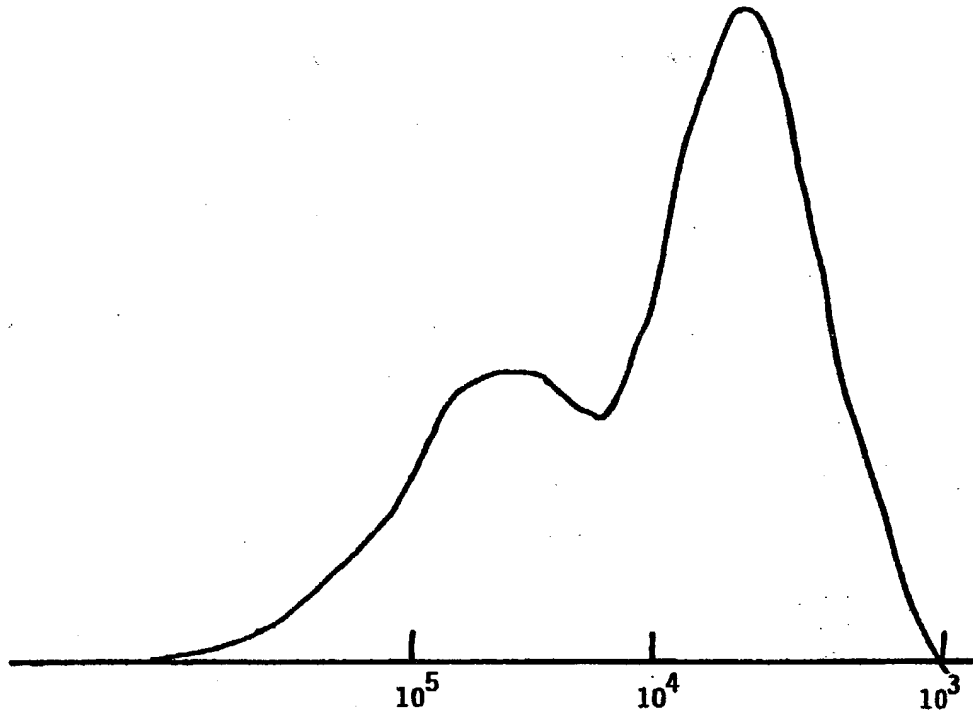


FIG. 4

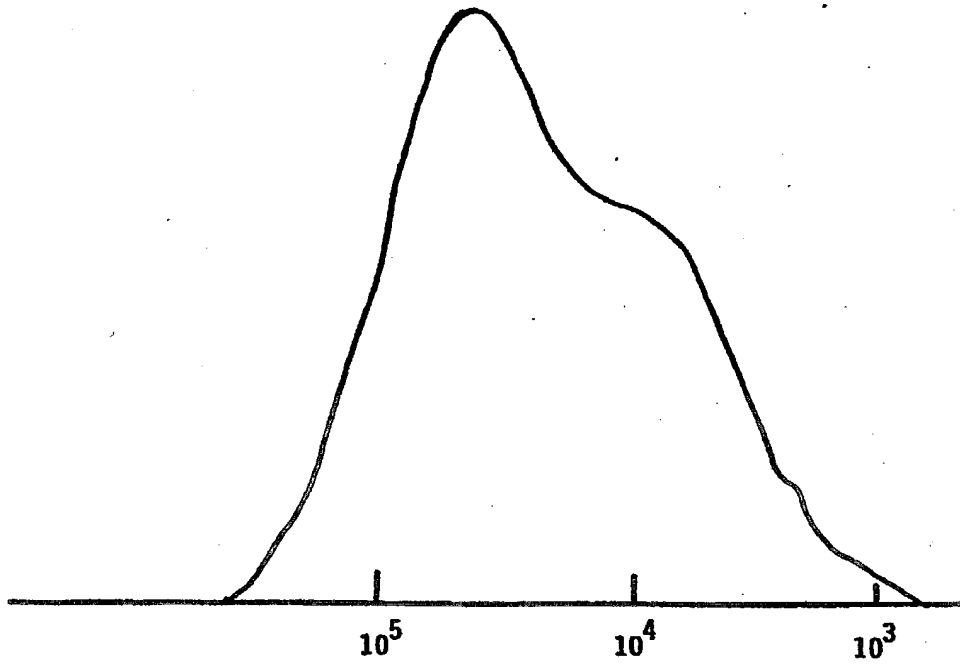


FIG. 5



DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. *)
A	EP-A-0 069 951 (HOECHST) * Claims 1-8 *	1	C 08 F 10/00 C 08 F 4/62
D,A	EP-A-0 035 242 (HANSJÖRG SINN) * Claims 1-2 *	1	
A	GB-A-1 233 599 (MONSANTO) * Page 1, line 61 - page 2, line 17 *	1	
			TECHNICAL FIELDS SEARCHED (Int. Cl. *)
			C 08 F
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 13-09-1984	Examiner WEBER H.
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			

